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MINING METHODS AND COSTS AT THE SOUTH BURNS SHAFT OF GOLDEN CONQUEROR MINES, INC., CRIPPLE CREEK, COLO.

BY

ALBERT S. KONSELMAN

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MINING METHODS AND COSTS AT THE SOUTH BURNS SHAFT OF GOLDEN CONQUEROR MINES, INC., CRIPPLE CREEK, COLO.[1]

By Albert S. Konselman[2]

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[2] One of the consulting engineers, Bureau of Mines, and mining engineer, Colorado Springs, Colo.

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INTRODUCTION

This paper describes the mining methods and operating costs for 1938 at the South Burns shaft, situated in the Cripple Creek district, Colorado.

The shaft is operated by Golden Conqueror Mines, Inc., through which portions of the properties of the Acacia Gold Mining Co., The Free Coinage Gold Mining Co., and The United Gold Mines Co. are worked under lease.

During 1938, 30,773.61 dry tons of ore averaging $9.58 in gold per ton was mined. Of this, 10,138.439 tons averaging $10.65 per ton was produced on company account, and 20,635.171 tons averaging $9.05 per ton was produced by "split-check" lessees.

ACKNOWLEDGMENTS

The writer appreciates the permission of the management of Golden Conqueror Mines, Inc., to publish this paper.

HISTORY OF MINE AND DISTRICT

The Cripple Creek district was first recognized as an important source of gold with the opening of the Stratton's Independence mine in 1891-92. Development was rapid, and by 1893 many mines were being operated; in that year production exceeded $2,000,000. Each year showed a marked increase, until 1900, when a peak output of $18,073,539 in gold was attained. Thereafter, production declined until 1932, when a low of $2,259,969 was produced.

Under the stimulus of lower costs and an advance in the price of gold, renewed activity commenced. In 1938 more than 521,000 tons of ore was mined, yielding $5,120,000, making a total recorded production of $382,094,0 in gold and silver.3/

3/ Bureau of Mines Metal Mining in Colorado in 1938; Preliminary Report: Min. Market Summary 685, January 1939, 13 pp. See also Mineral Resourc Geol. Survey and Bureau of Mines, and Minerals Yearbook, Bureau of Mine

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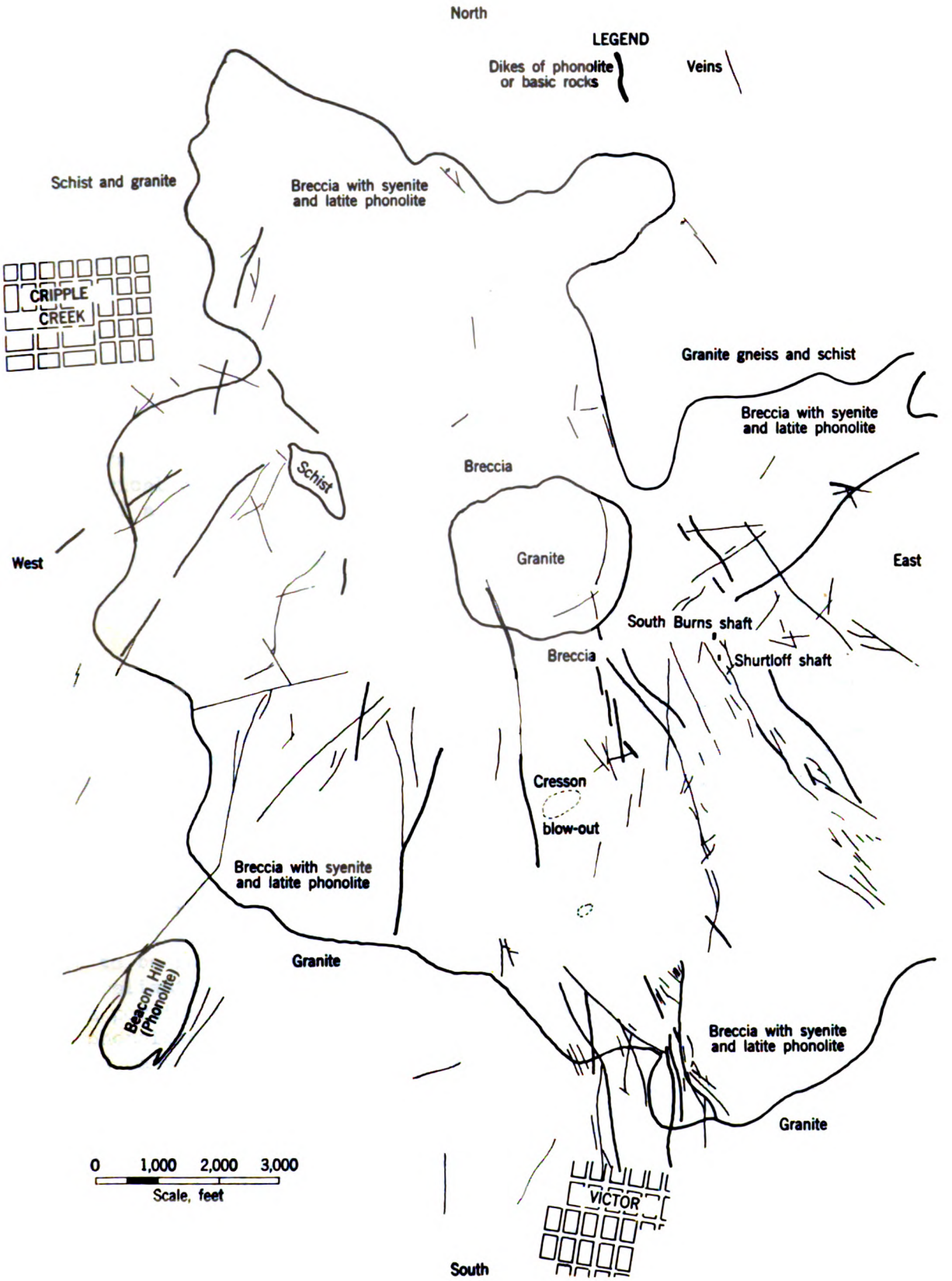

Figure 1.—Portion of Cripple Creek district, Colo., showing dikes and principal fissures.

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With few exceptions (notably the Cresson mine) the properties now operating were known before 1900.

The area tributary to the South Burns shaft formerly was worked through five separate shafts, the combined production of which may have been as high as $10,000,000. This shaft was commenced in 1901 and reached a depth of 1,575 feet by 1919. Levels were extended north and south of the shaft, and contemporary activity of neighboring mines resulted in connecting workings as deep as the 14th level.

In 1936 the present operators were able to consolidate the ground under one operation, and production has increased steadily since that time. Virtually all ore has been mined from newly developed ground.

GEOLOGY

Several examinations of the Cripple Creek district have been made by the Geological Survey.4/ The recent work of Loughlin and Koschman5/ has resulted in a new conception of the origin of gold deposits in the district.

The principal structure of the district is a roughly elliptical mass of volcanic material of Miocene age occupying a craterlike depression 3 miles wide by 4 miles long in pre-Cambrian gneiss, schist, and granite. (See fig. 1.)

The volcanic material is mainly a consolidated breccia, the fragments of which range in size from small grains (tuff) to angular blocks several feet in diameter. Near the contacts with surrounding walls, many fragments of the enclosing wall rocks are found, but the great mass of the breccia is composed of fragments of all the Cripple Creek intrusives, phonolite and latite-phonolite being dominant.

At about the center of the breccia mass is an island of granite, and west of this is a smaller island of schist. These islands lie opposite projections from the rim, indicating a buried ridge of crystalline rock that divides the crater into north and south portions. Below each of these are thought to be subcraters, through the vents of which the eruptive material and mineralization came and above which the greater enrichment exists. The southern portion of the crater has been by far the more productive. Basic rocks, phonolite, latite, and syenite in the form of dikes, sills, chimneys, and large masses intrude the breccia.

4/ Cross, Whitman, and Penrose, R.A.F., Geology and Mining Industries of the Cripple Creek District, Colo.: 16th Ann. Rept., Geol. Survey, 1894-95 (1896), pt. II-a, pp. 1-209. Lindgren, Waldemar, and Ransome, F.L., Geology and Gold Deposits of the Cripple Creek District, Colo.: Geol. Survey Prof. Paper 54, 1906, 516 pp.

5/ Loughlin, G. F., and Koschman, A. H.: Proc. Colorado Sci. Soc. Vol. 13, No. 6, 1930.

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Fracture zones have developed within the breccia mass and, notably in the southern and southeastern part of the district, extend into the crystalline rim. Although the major fractures have a general northerly trend and tend to converge toward the granite island, important fracturing has taken place in all directions of dip and strike. These fractures form sheeted zones or a series of veins penetrating all types of rock, and many have proved productive without regard to the nature of their walls.

Southwest of the main crater ore has been developed at the periphery of an isolated plug of phonolite (Beacon Hill). The largest production came from shafts on the west side of this plug from a fracture zone extending north, far into the breccia mass; the South Burns shaft is on one of the more persistent of the southeastern system of fractures.

The local structure is breccia overlain by a thick mass of latite and latite phonolite. The relation is shown on the section of figure 2. Extending from the latite mass are two latite dikes with a westerly strike, and, running through this structure in a generally north-south direction, are nearly vertical dikes of phonolite, latite-syenite, syenite, and basic rocks. (See figs. 2, 3, and 4.)

Earlier prospecting was confined to two principal veins - the Shurtloff and the Eagles. On the Shurtloff, which strikes northwest, a small stope was mined from the surface to below the 3d level. This was entirely in the latite. Nothing more was found until the 7th level cut the tops of an ore-shoot that extended to the 10th level. From the 7th to below the 8th level part of the west wall of this ore is breccia. Below this level both walls are in breccia. This ore shoot is 400 feet long and over 12 feet thick between the 7th and 8th levels. Exploration failed to find profitable ore on the vein on either the 11th or 12th levels.

The Eagles vein, which strikes northeast, is barren in the latite, but ore was stoped from a point near its entrance into the breccia below level 9 to a point above level 15.

The veins converge to the south at a point a short distance south of the shaft where a large stope was mined between the 7th and 8th levels from the breccia near the indistinct breccia-latite contact. A complicated system of vertical and flat seams occurs south and east of this stope between the 8th and 11th levels. These seams, which individually are very narrow and dip and strike in all directions, are the immediate source of ore.

Above the 10th level the seams form a thick, nearly horizontal, sheeted zone following a general stratification of the breccia, having the appearance of a water-lain deposit. Vertical fissures have carried mineralization above and below the 10th level. On the 9th level the bedding is not so apparent. Here fracturing forms vertical sheeted zones, and slips cut off by other slips give an appearance of jointing.

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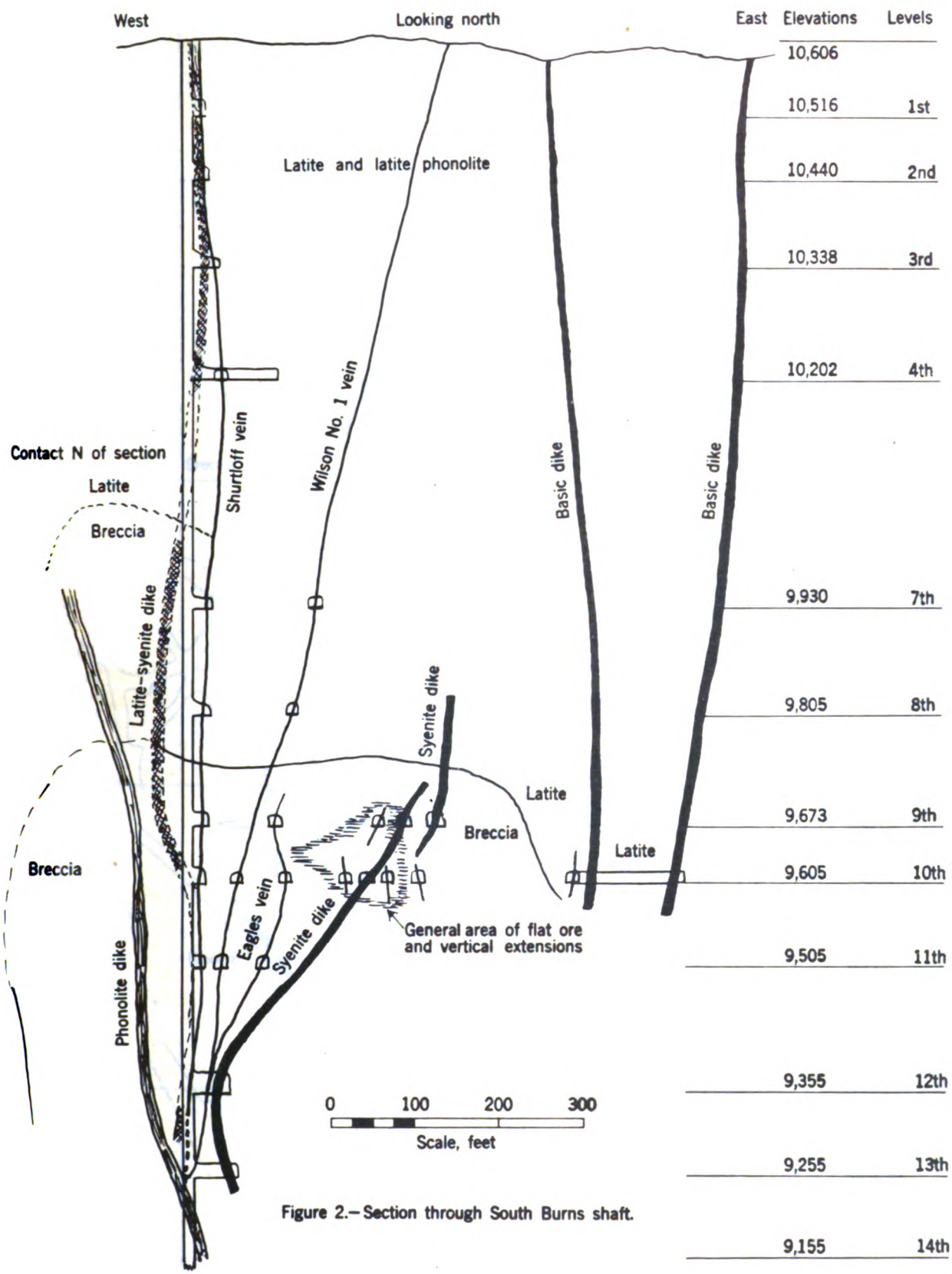

Figure 2.—Section through South Burns shaft.

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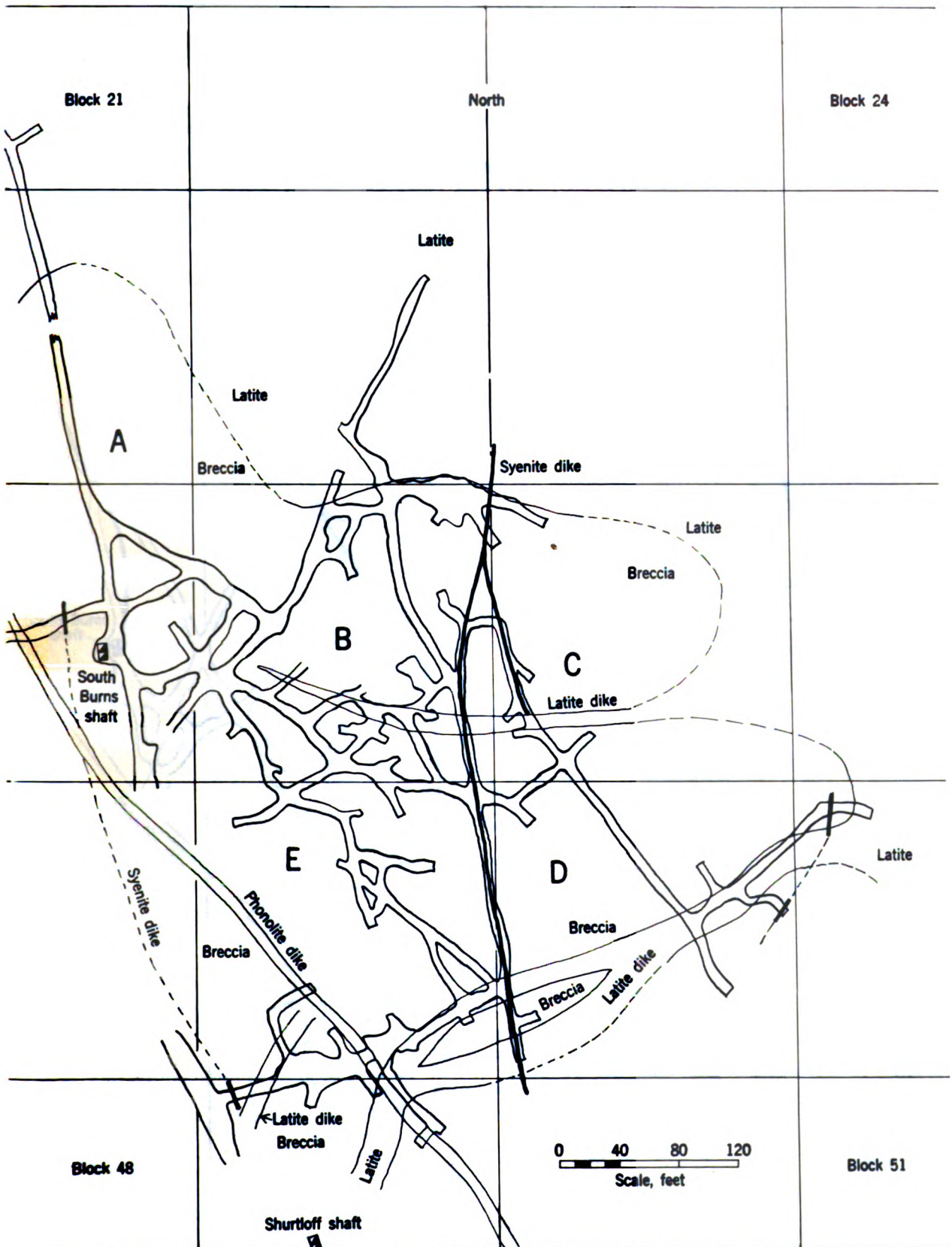

Figure 3.—South Burns shaft, Cripple Creek district, portion of 9th level, elevation 9,673 feet.

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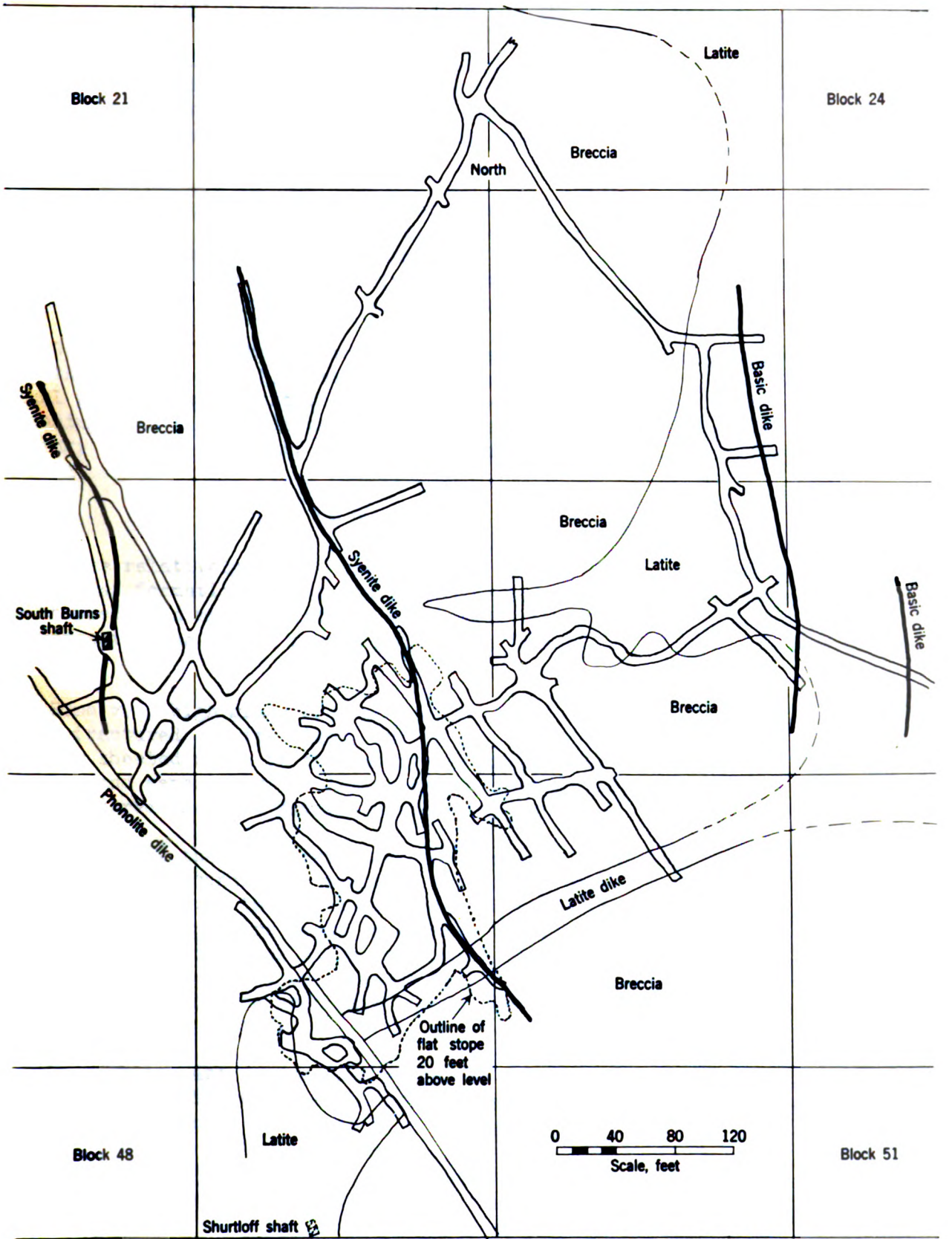

Figure 4.—South Burns shaft, Cripple Creek district, portion of 10th level, elevation 9,605 feet.

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PHYSICAL CHARACTERISTICS OF ORE AND ENCLOSING ROCKS

The physical character of the ore and wall rocks and the size, shape, and attitude of individual ore shoots govern the choice of stoping methods. The wall rocks are hard and stand well and are suited to open-stope and shrinkage methods. Dikes cutting through the ore stand as well as the other rocks.

The better-grade ore is confined to seams, and the intervening rocks are low-grade or barren; however, it is necessary to break much low-grade material to recover the richer seams. In stoping, the rock breaks into large blocks requiring secondary blasting, but the values are largely in the fines and subsequently can be partly separated by screening.

Generally, for the purpose of stoping, ore shoots can be separated into three classes - (1) flat ore bodies mined by open-stoping, leaving casual pillars to support the back, (2) narrow vertical ore shoots or those extending only a short distance above a level, which are mined by open-stoping; and (3) vertical, wide ore shoots, which are mined by shrinkage stoping.

METHODS OF PROSPECTING AND EXPLORATION

Since relatively little ore has been found in the latite at the South Burns, that formation is not considered promising, and at present headings are stopped when massive latite is reached. Sometime this formation will be prospected, as it has proved productive in neighboring mines to the east and west.

Some very high grade ore has been found on breccia-latite contacts and within fractured syenite dikes, but by far the greater production has been won from sheeted zones in the massive breccia alone, hence such zones in breccia, and especially the intersection of two such zones at an acute angle, are considered the most favorable places to prospect.

A study of the old workings of the mine and maps of adjacent mines indicates where such conditions might be expected. Where no such data exist, crosscuts are driven in search of fractures of sufficient promise to warrant following. One fracture leads to another until a complicated pattern of workings is developed, as shown in figures 3 and 4 of the 9th and 10th levels. Ore is followed until waste is reached. It often happens that a cross seam cuts off the ore; this second seam may continue in ore until another seam cuts it off.

Where veins are as numerous as on the 9th and 10th levels, all unexplored blocks within the breccia eventually will be cut. Such areas are marked A, B, C, and D on figure 3.

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METHODS OF SAMPLING AND ESTIMATION OF TONNAGE AND GRADE

A certain hardness, color, and texture of the rock and presence of fluorite in small seams or vugs are good but not infallible indications of ore. Grab samples are taken of each round broken, and a more accurate box sample is obtained at the end of the shift.

Gold occurrences are erratic. Most, if not all, of the gold may be in the seams or on the faces of broken ore; however, it is advisable occasionally to sample the coarse and fine material separately or to sample the streaks in the breast and the interposed rock separately.

All assays are recorded on suitable plans. Material containing 0.20 ounce gold per ton or over is considered ore; coloring on maps indicates the areas over which such values are obtained. From these maps, and in conjunction with stope maps, volumes are computed. For ore in place, 14 cubic feet per ton, and for broken ore, 20 cubic feet per ton are the weight factors employed. Tonnage is reported as "in sight and probable". Limits of probable ore are closely drawn to exposures, due to the nature of the deposit. Usually a projection of 20 feet beyond known ore is allowable, but this distance varies with conditions. An average of the grab and box samples, corrected to mill returns and applied to the balance of the reserve, has been found satisfactory in estimating the grades.

A large proportion of the tonnage in reserve was developed by lessees.

METHODS OF DEVELOPMENT

All work is done through a vertical two-compartment shaft 1,575 feet deep. Each compartment is 4 by 4 feet inside and timbered with 3- by 8-inch cribbing.

Thirteen levels at irregular intervals (see fig. 2) had been driven by former operators; present exploring is done in virgin areas on these old levels. Drifts are 5 by 7 feet and raises 4 by 8 feet in cross section; where necessary, full-size intermediate drifts are run from raises. No timbering is necessary, except for chutes and manways.

Leyner-type drifting machines mounted on columns or crossbars and self-rotating stopers are used for drilling. One and one-eighth-inch hollow round steel is being replaced with 1-inch hollow hexagonal steel shanked to fit the 1-1/8-inch round chuck. Less breakage has resulted from this change. Stopers use 1-inch hollow quarter-octagon steel. Detachable bits were tried and rejected. The usual practice is to give the driller a clean set-up.

Fifteen to twenty-two holes loaded with 70 to 100 cartridges of 1-1/8- by 8-inch, 45-percent-strength, Atlas Powder will break 3 to 4 feet of ground. Dry sand stemming is used in Leyner rounds. Twenty to 35 pieces of steel are used per round. Bits are of the single 1^{4}6 taper type.

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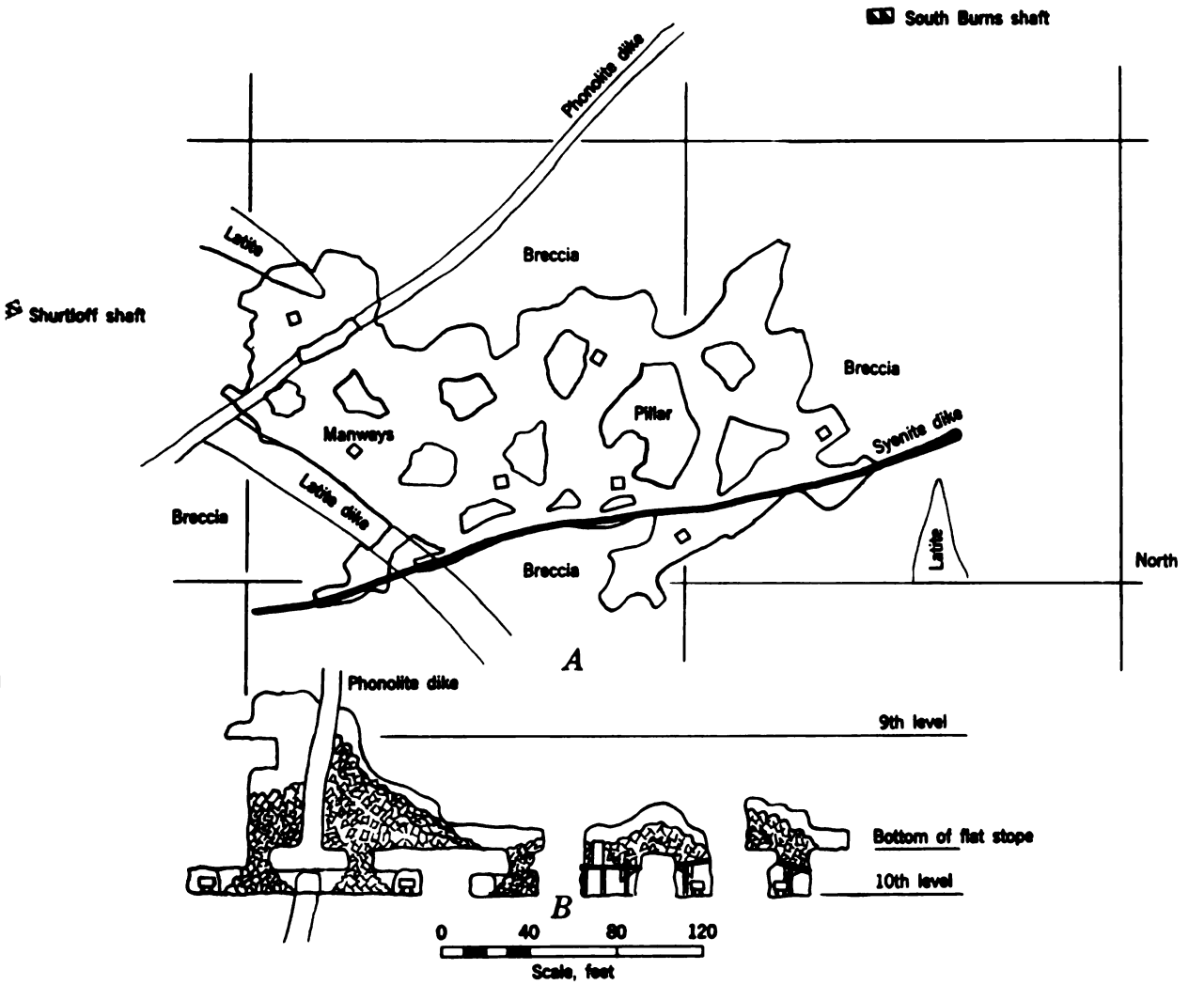

Figure 5.—Flat open stope. *A*, Plan above 10th level; *B*, north–south section, showing method of drawing ore from stope.

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Starters are 2-1/4-inch and finishers 1-7/8-inch gage for Leyner steel and 2- to 1-3/4-inch for stoper steel. In drifting, the ordinary down-cut round is used. The "burnt-cut" round rarely is found effective for drifts but is used for driving small raises.

In a burnt-cut round, a center hole is drilled first and then a circle of holes is drilled around it, the remaining holes being spaced to shape the excavation. In drifts all holes except back holes and lifters are horizontal, while in raises they are vertical. The center hole is left unloaded. The rest are heavily loaded and timed to break to the center. This type of round finds its principal use where lack of space prevents enough angle of cut in raises and in "spongy" ground in drifting.

METHODS OF MINING

Flat Open Stopes

A flat open stope is being mined above the 10th level. This ore body originally was found by raising on seams that were followed on the 10th level. About 18 feet above the level a definite flat sheeted zone was cut, above which the walls continued to show ore. Using this "flat" as a bottom, rooms were excavated by slabbing the walls with Leyners. These rooms connected with other rooms similarly opened, until the "flat" shown in figure 5 was developed.

Casual pillars were left to support the back, and an 8-foot section was excavated to assay-wall limits. As far as now developed, a north-south syenite dike containing exceptionally good ore (1.00 ounce plus) generally limits mineralization to the east. On the south a barren latite dike cuts through the flat, and beyond this little work has been done.

On the southeast a barren phonolite dike cuts through the flat ore. The west and north extensions are limited by assay walls. Drifts extended to the south on the 10th level indicate possible continuation of the flat ore in that direction. Work on the next level above (the 9th) has proved continuity of much vertical ore through the flat, so that as the flat ore is recovered, overhand open stoping and shrinkage are also carried on.

In addition to pillars of ore and waste dikes no support is needed in the flat stopes other than a few stulls to prevent blocks from dropping out of the back.

A tendency to break into large blocks has influenced the method of blasting, and also the method of drawing off the ore. In slab rounds in the horizontal breast, it has been found that by drilling long holes and slipping an 8-inch stick of wood between two sticks of powder, thus distributing the powder along the hole (rather than concentrating it toward the end), better breaking is accomplished. The disadvantage is in additional fumes from the wood.

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Overhand drilling in high flat stopes yields great blocks of ore that cannot be drawn through the wooden chutes. To overcome this difficulty, short crosscuts are driven from the main drift, from the ends of which large raises are driven to the stopes. The ore is let down on mucking platforms placed on the level where it is more easily handled and shoveled into cars. Cribbed manways 4- by 4-feet in cross section are carried through the broken ore. The section on figure 5 illustrates the above description.

Vertical Open Stopes

In places where the ore does not extend over 25 feet above the level, no timber is used other than for staging; the ore is blasted on shoveling sheets placed on the level and is shoveled into cars by hand.

In narrow, vertical ore shoots stopes are not filled with ore, the driller working from stulls and planking. The ore is handled either through chutes or, if the amount is small, shoveled off the level. These stopes generally follow rich seams and require careful mining to avoid dilution by the barren wall rock. The usual method employed is to drill and shoot the seam heavily, breaking it as finely as possible. The walls are then drilled and shot lightly, bringing the excavation to stoping width but breaking the waste in large pieces. Thus, the fine ore will pass through the ore house screens and the coarse waste can be discarded.

Shrinkage Stopes

Shrinkage stopes are used in wide vertical ore bodies. The level is stulled with 10-inch round timber and lagged with 6-inch round lagging. Chutes are built of 3-inch planking and are 4 by 4 feet at the mouth. Planks held by wooden cleats are used as chute gates. Where stopes are narrow enough manways are kept open at the ends by stulls and lagging. Otherwise they are cribbed through the broken ore. Backs are carried up with stopers; seams going into the walls are followed with Leyners. After the stope is completed, and as it is being drawn, jackhammers are used to bench down any ore that might be left in the manway ends or walls. An occasional pillar or stull prevents the walls from sloughing as the broken ore is withdrawn.

TRANSPORTATION

Ore is loaded from chutes or shoveled into 16- and 18-cubic-foot mine cars and trammed over 12-pound rails to the shaft station. Here it is dumped into a Duralumin skip (42 cubic feet capacity) and hoisted to the surface. A single-drum, 150-horsepower, electric hoist takes the load to the surface at 630 feet per minute; the ore is dumped into a shaft hopper, from which it is trammed to the proper bin.

SCREENING AND SORTING

Bins are equipped with grizzlies, screens, and sorting tables, as shown in figure 6. Very little hand-sorting is done, most of the ore by-passing the tables.

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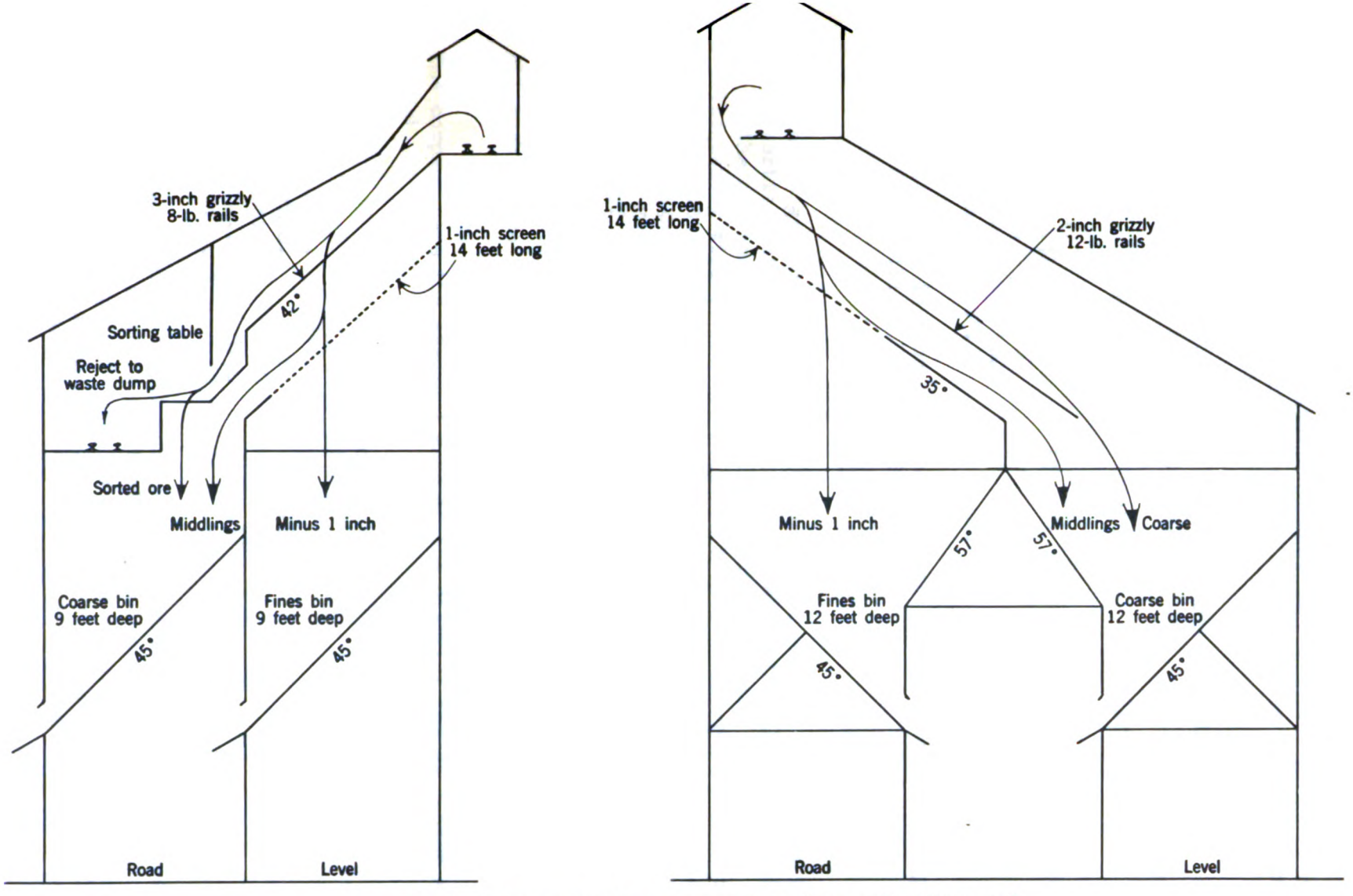

Figure 6.—Sorting and screening arrangement in ore houses at South Burns shaft.

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Royalties, freight, and treatment charges vary with the grade of carload lots, and the preparation of the ore in the ore house has an important bearing on the net return to the shipper.

The effect of screening, without rejecting any waste by sorting, is shown for a portion of the ore mined in 1938:

	Mined ore	Coarse	Screenings	Reject
Dry tons.....	15,157	12,636	2,521	None
Value.....	$133,278.01	$83,783.71	$49,494.30	None
Percent tons...	100	83.4	16.6	None
Percent value..	100	62.8	37.2	None
Value per ton..	$8.79	$6.63	$19.63	None

Ore from the bins is trucked by contract to the railroad and shipped to the Golden Cycle mill at Colorado Springs.

PERCENTAGE OF EXTRACTION

Because the ground stands so well, nearly 100 percent of the ore is extracted in vertical stopes. In the flat stope above the 10th level, 18 percent of the ore has been left in pillars supporting the backs, much of which subsequently will be mined. Dilution by overbreakage is considerable, and relatively little waste is sorted out either above or below ground. The ore is sold outright to the Golden Cycle mill and is paid for on a basis of $32.76 per ounce gold on 100 percent of the assay, a recovery to the miner of 93.6 percent of the gold value.

WAGE AND LEASE SYSTEMS EMPLOYED

All work at the South Burns shaft is done under lease or on company account.

The company pays the standard wage of the district for an 8-hour shift, as follows:

Class	Wage per shift	Accident compensation at 6.79 percent	Payroll tax at 4 percent	Total
Surface labor.....	$4.25	$0.29	$0.17	$4.71
Miners and timbermen.	4.85	.33	.19	5.37
Muckers and trammers.	4.25	.29	.17	4.71
Hoistmen.....	5.50	.37	.22	6.09
Blacksmith.....	5.50	.37	.22	6.09

Leases are granted on one or more blocks of ground 200 feet on a side, two levels deep. The lessee is required to do a minimum of two shifts of work per day per block, pay his compensation and payroll tax, and use and repair his own drilling equipment. The company supplies all other tools and all services. After delivery of the ore to the bin, expenses and returns

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are divided equally between the company and the lessee. This is known as the split-check system and is commonly used in the Cripple Creek district.

A comparison of costs per ton for the year 1938 is given:

Type work	Labor	Company direct	Company indirect	Company total	Grand total	Percentage by company
Lessee A....	$1.40	$0.93	$0.66	$1.59	$2.99	53.2
Lessee B....	1.24	1.69	.69	2.38	3.62	65.8
Lessee C....	1.46	.99	.62	1.61	3.07	52.5
Lessee D....	-	-	-	-	-	67.0
All lessees.	1.49	1.13	.66	1.79	3.28	54.5
Company.....	1.40	1.20	.66	3.26	3.26	100.0
Mine average	1.47	1.15	.66	2.28	3.28	69.5

Type A is a group of lessees doing very little exploration work, their production coming from old stopes. Type B does much exploring with relatively small production. Type C is a lease producing a large tonnage and doing much development work in ore and in waste. Type D has done considerable development work without any production.

"All lessee" costs are calculated against tonnage produced by lessees only. "Company" costs are calculated against ore produced by company operations only, but "mine average" costs include both company and lessee expense and are computed against all ore hoisted.

An analysis of these costs shows virtually no difference in total cost between company and lease operations under 1938 conditions. As shown by the above tabulation, the average lessee had $1.49 invested in labor in each ton of ore he produced while the company had $1.79 invested in supplies and services, or 54.5 percent of the total cost of the ore. Thus, the average lease made a profit of 30 cents per ton before the company broke even on the bare extraction cost.

VENTILATION

Through very old workings, the South Burns is connected with other mines of the district and from level to level through open stopes. The ventilation is generally good except in the new workings, where gases from blasting are noxious at times. Connections are made as quickly as possible, and natural ventilation is depended upon entirely.

Basic dikes when cut by mine headings, are thought to be the source of a small quantity of gas. The pure gas is largely nitrogen and carbon dioxide, which exudes from the rock at times of falling barometric pressure. Rarely is the quantity sufficient to extinguish a light, and then only close to its source.

COSTS AND PERFORMANCE

Monthly cost sheets are prepared showing a general segregation of expenses. For the year 1938, when 30,773.6 dry tons was mined, the average cost for the various items was as follows:

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Item		Cost per ton hoisted
Company payroll		1/ $1.009
Power:		
General power	$0.169	
Station and surface lighting	.014	
Connected load charge	.125	.308
Powder		.508
Timber		.052
Other supplies:		
General supplies	.134	
Small tools	.001	
New steel	.078	.213
Miscellaneous:		
Telephone	.001	
Assay expense	.093	
Truck expense	.012	
Hoisting royalty	2/ .020	
Insurance	.012	
Miscellaneous small expense	.048	.186
Total company expense		2.276
Lessees' expense		1.002
Total expense		3/ 3.278

1/ Includes compensation, premium, and payroll taxes.
2/ Shaft rental for hoisting outside ore.
3/ Before depreciation and other taxes.

These general items of cost are broken down and distributed to the various services, and these in turn are charged to each lease block or company operation as used.

Two general groups of charges are recognized. Indirect charges are all those that enter in the cost of servicing the mine as a whole. Their total is virtually constant from month to month, and it will not vary unless a very substantial and continued drop or rise in production takes place. They include hoist and top men, superintendent's and mine office payroll, connected-load charges, insurance, etc., as items of fixed expense, and mine and surface lights, truck operations, telephone, etc., as items of general expense.

Direct charges are for underground labor, materials, assays, power for air, hoisting, and other purposes and constitute the additional cost that each operation entails.

Thus, the total of indirect charges should remain fairly constant as long as the mine produces in the neighborhood of 3,000 tons per month. The indirect cost per ton will vary. On the other hand, the cost per ton of direct charges will not vary greatly, but its total will rise or fall as the tonnage changes.

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Over 1938 the average costs of mining were:

Item	Cost per ton hoisted
Labor (company and lease)	$1.482
Air	.107
Powder	.508
Assays	.093
Supplies	.125
Hoisting	.070
Sharpening	.154
New steel	.079
Total direct	2.618
General expense	.132
Fixed expense	.528
Total indirect	.660
Total operating	3.278
Depreciation, plan, and equipment	.182
Taxes, plan, and equipment	.011
Total mine cost	3.471

The above included the cost of 3,775 feet of development and exploration and an increase of 2,000 tons in broken ore in stopes.

DEVELOPMENT COST, 2,036 FEET

Item	Direct cost per foot 9th level	12th level
Labor	$3.894	$3.727
Powder	1.683	1.350
Supplies	.431	.377
Air	.386	.326
Steel	.282	.238
Sharpening	.558	.471
Total	1/ 7.234	2/ 6.489

1/ Includes slabbing for turn-outs, widening drifts, and intermediate work.
2/ Straight drifting.

The following tables give some performance data for 1938:

DEVELOPMENT PERFORMANCE

Item	9th level	12th level
Pounds powder per foot of advance	10.81	8.47
Holes drilled per machine shift	16.7	17.4
Sticks powder per round	94.8	87.9
Sticks powder per hole	5.6	5.0
Feet advanced per machine shift	1/2.96	2/3.50

1/ Over-all development cost on 9th level includes slabbing for turn-outs, widening drifts, and intermediate work.
2/ Straight drifting on 12th level.

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GENERAL PERFORMANCE

Powder cost per kw.-hr.	$0.01748
Kw.-hr. consumed per ton.....	16.123
Steel cost per machine shift.....	$.834
Tons broken per machine shift.....	11.02
Sharpening cost per machine shift.....	$1.65
Air cost per machine shift.....	$1.14
Pounds powder used per ton.....	2.89
Bits sharpened per machine shift (all machines).....	13

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